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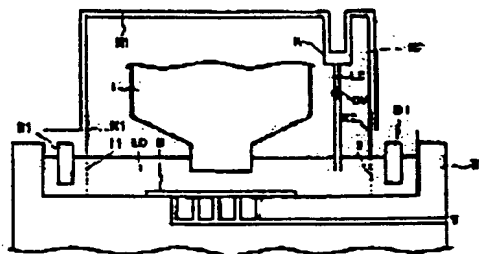
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(22)Date of filing : 10.06.1997 (72)Inventor : KUDO TAKETO

## (54) ALIGNER, ITS MANUFACTURE, EXPOSING METHOD AND DEVICE MANUFACTURING METHOD

### (57)Abstract

**PROBLEM TO BE SOLVED:** To enable continuous correction of imaging performance without vibration, by installing a refractive index adjusting means for adjusting the refractive index of liquid.

**SOLUTION:** A refractive index adjusting means consists of the following; electrodes D1, ion exchange films 11, 12, bulkheads K1, K2, exhaust pipes H1, H2, a mixer K, an electromagnetic valve DV, an introducing pipe LD, a power source supply part and a second control part. The second control part sends a command to the power source supply part, and applies a specified voltage for a specified period across the two electrodes D1. From one electrode turning to an anode, oxygen gas is generated. From the other electrode turning to a cathode, mixed gas of hydrogen and chlorine is generated. Since the concentration of hydrogen chloride in liquid LQ is decreased, the refractive index of the liquid LQ is decreased. The second control part sends a command to the electromagnetic valve DV, in order to open the valve DV and add high concentration admixture aqueous solution to the liquid LQ. Thereby the refractive index of the liquid LQ is increased.



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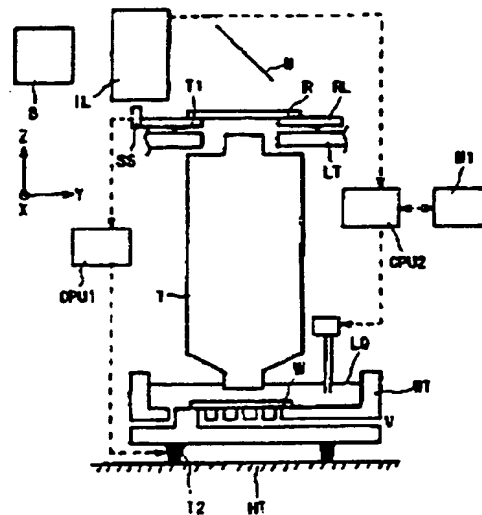
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(54)【発明の名称】 偏光膜及びその製造方法並びに偏光方法及びデバイス製造方法

(57)【要約】

【課題】、連続的な結像性能の補正を振動を伴うことなく可能とすること、或いは投影光学系の開口数の増大及び結像性能の補正を両立すること

【解決手段】レチクルR上に設けられたパターンを照明する照明光学系1と、このパターンの像を感光性基板上に形成する投影光学系2とを有し、投影光学系と感光性基板との間の光路中の少なくとも一部分に位置する液体LQを介して露光を行う露光装置であって、液体の屈折率を調整するための屈折率調整手段を有する。



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【特許請求の範囲】

【請求項1】 レチクル上に設けられたパターンを照明する照明光学系と、該パターンの像を感光性基板上に形成する投影光学系とを有し、前記投影光学系と前記感光性基板との間の光路中の少なくとも一部分に位置する液体を介して露光を行う露光装置において、前記液体の屈折率を調整するための屈折率調整手段を有することを特徴とする露光装置。

【請求項2】 前記屈折率調整手段は、前記投影光学系の結像性能を補正するように前記液体の屈折率を調整することを特徴とする請求項1記載の露光装置。

【請求項3】 前記投影光学系の結像性能を測定する結像性能測定手段をさらに備え、

前記屈折率調整手段は、前記結像性能を補正するように前記液体の屈折率を調整することを特徴とする請求項2記載の露光装置。

【請求項4】 前記投影光学系の結像性能の変動の要因の状態を検知する変動要因検知手段をさらに備え、

前記屈折率調整手段は、前記要因の状態に応じて、前記結像性能を補正するように前記液体の屈折率を調整することを特徴とする請求項1記載の露光装置。

【請求項5】 前記照明光学系は、前記レチクルに対する照明条件を変更可能に構成され、前記変動要因検知手段は、前記照明条件の状態を検知し、

前記屈折率調整手段は、前記照明条件の変更に応じて、前記結像性能を補正するように前記液体の屈折率を調整することを特徴とする請求項4記載の露光装置。

【請求項6】 前記変動要因検知手段は、前記レチクルの種類を判別するものであり、

前記屈折率調整手段は、前記レチクルの種類に応じて、前記結像性能を補正するように前記液体の屈折率を調整することを特徴とする請求項4記載の露光装置。

【請求項7】 前記感光性基板を保持する感光性基板ホルダーをさらに備え、

該感光性基板ホルダーは、前記投影光学系と前記感光性基板との間の光路を前記液体で満たすための側壁と、前記液体を前記感光性基板ホルダーへ供給すると共に前記感光性基板ホルダーから回収するための供給・回収ユニットとを備えることを特徴とする請求項1乃至6の何れか一項記載の露光装置。

【請求項8】 前記屈折率調整手段は、前記液体に屈折率を調整するための添加剤を供給する添加剤供給ユニットと、前記液体から前記添加剤を回収するための添加剤回収ユニットとを有することを特徴とする請求項1乃至7の何れか一項記載の露光装置。

【請求項9】 所定の照明条件のもとでレチクルを照明する工程と、前記レチクル上に設けられたパターンを投影光学系を用いて感光性基板上に転写する工程とを含み、前記投影光学系からの光を所定の液体を介して前記感光性

基板へ導く露光方法において、

前記投影光学系の結像性能を補正するために、前記液体の屈折率を調整する工程を含むことを特徴とする露光方法。

【請求項10】 所定の照明条件のもとでレチクルを照明する工程と、前記レチクル上に設けられたデバイスパターンを投影光学系を用いて感光性基板上に転写する工程とを含み、前記投影光学系からの光を所定の液体を介して前記感光性基板へ導くデバイス製造方法において、

前記レチクル及び前記照明条件のうち少なくとも一方が変更されたときに、前記液体の屈折率を変更することを特徴とするデバイス製造方法。

【請求項11】 レチクル上に設けられたパターンを照明する照明光学系と、該パターンの像を感光性基板上に形成する投影光学系とを有し、前記投影光学系と前記感光性基板との間の光路中の少なくとも一部分に位置する液体を介して露光を行う露光装置の製造方法において、前記投影光学系の結像性能を測定する工程と、

該測定された結像性能に基づいて、前記液体の屈折率の初期値を定める工程とを含むことを特徴とする露光装置の製造方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】 本発明は、レチクル上に設けられたデバイスパターンのを感光性基板上に投影する投影光学系を備えた露光装置及び該露光装置を用いた露光方法並びにデバイス製造方法に関する。さらに詳しくは、本発明は投影光学系と感光性基板との間の光路に液体を充填した液浸型露光装置に関する。本発明は、半導体素子、撮像素子（CCD等）、液晶表示素子、または薄膜超伝導ヘッド等を製造する際に好適なものである。

【0002】

【従来の技術】 光学系の最終面と像面との間の空間を、ワーキングディスタンスと言うが、従来の露光装置の投影光学系ではワーキングディスタンスは空気で満たされていた。ところで、ICやLSIを製造する過程に於いてシリコンウエハに露光するパターンは、その微細化が常に望まれていて、そのためには露光に用いる光の波長を短くするか、あるいは像側の開口数を大きくする必要があり、光の波長が短くなるにつれ、満足できる結像性能を得つつ露光に十分な光量を確保できるだけの透過率を持つガラス材料は少なくなってくる。

【0003】 そこで像面までの最終像を、空気より屈折率の大きい、液体にすることで像側の開口数を大きくすることが提案されていて、そのように液体を用いた投影光学系を持つ露光装置は、液浸型露光装置と呼ばれている。さて、露光装置においては、投影光学系の結像性能を補正するために、投影光学系の最も物体側の光路或いは最も像側の光路中に、結像性能を調整するための結像性能補正部材を交換可能に設ける技術が知られてい

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る。

【0004】

【発明が解決しようとする課題】しかしながら、液浸型露光装置では、投影光学系と感光性基板との間の光路（ワーキングディスタンス）に液体を満たす構成であるため、結像性能を補正するための部材を配置することが困難である。また、このような結像性能補正部材は、有限の数、現実的な装置の構成を考えると数個程度しか準備することができないため、離散的にしか結像性能を補正できない問題点がある。

【0005】また、投影光学系の結像性能は所定の許容範囲に収める必要があるが、上述のように結像性能の補正が離散的にしかできないければ、この所定の許容範囲内に収めることが困難となる。特に、露光パターンが微細化や露光面積の増大が求められると、この結像性能の許容範囲が狭くなり、また、レチクルと感光性基板とを走査させつつ露光を行う走査露光方法を行う場合にも結像性能特性の変動幅の許容範囲が狭くなっており、離散的な補正では対応しきれない。

【0006】また、上述のような結像性能補正部材の交換時において、投影光学系自体の振動が発生するため、結像性能へ悪影響が生じる恐れもある。そこで、本発明は、連続的な結像性能の補正を振動を伴うことなく可能とすることを第1の目的とする。また、本発明は、投影光学系の開口数の増大と結像性能を補正することとの両立を第2の目的とする。

【0007】

【課題を解決するための手段】上述の第1の目的を達成するために、本発明による露光装置は、レチクル上に設けられたパターンを照明する照明光学系と、このパターンの像を感光性基板上に形成する投影光学系とを有し、投影光学系と感光性基板との間の光路中の少なくとも一部分に位置する液体を介して露光を行う露光装置であって、液体の屈折率を調整するための屈折率調整手段を有するものである。

【0008】ここで、上記請求項2に掲げた好ましい態様によれば、屈折率調整手段は、前記投影光学系の結像性能を補正するように液体の屈折率を調整するものである。この構成に基づいて、請求項3に掲げた好ましい態様によれば、投影光学系の結像性能を測定する結像性能測定手段をさらに備えるものであり、屈折率調整手段 \*

\*は、前記結像性能を補正するように液体の屈折率を調整するものである。

【0009】また、請求項4に掲げた好ましい態様によれば、投影光学系の結像性能の変動の要因の状態を検知する変動要因検知手段をさらに備えるものであり、屈折率調整手段は、要因の状態に応じて、結像性能を補正するように液体の屈折率を調整するものである。この構成に基づいて、請求項5に掲げた好ましい態様によれば、照明光学系は、前記レチクルに対する照明条件を変更可能に構成され、変動要因検知手段は、照明条件の状態を検知し、屈折率調整手段は、照明条件の変更に応じて、結像性能を補正するように液体の屈折率を調整するものである。

【0010】そして、請求項6に掲げた好ましい態様によれば、変動要因検知手段は、レチクルの揺動を検知するものであり、屈折率調整手段は、レチクルの種類に応じて、結像性能を補正するように液体の屈折率を調整するものである。また、上述の第2の目的を達成するためには、投影光学系と感光性基板との間の光路の全てを液体で満たすことが好ましい。このとき、本発明による露光装置は、投影光学系と感光性基板との間の光路を前記液体で満たすための調整と、液体を前記感光性基板ホルダーへ供給すると共に前記感光性基板ホルダーから回収するための供給・回収ユニットとを備え、感光性基板を保持する感光性基板ホルダーをさらに有することが好ましい。

【0011】また、屈折率調整手段は、液体に屈折率を調整するための添加剤を供給する添加剤供給ユニットと、液体から前記添加剤を回収するための添加剤回収ユニットとを有することが好ましい。

【0012】

【発明の実施の形態】上述の構成のごとき本発明においては、投影光学系と感光性基板との間の光路中に位置する液体の屈折率を調整することができるため、この屈折率の変化により投影光学系の結像性能を補正することができる。ここで、屈折率調整の手法としては、液体が多物質の混合液体であるとする、この混合液体の屈折率  $n$  は、ローレンツ・ローレンス (Lorentz-Lorenz) の式に従い、

【0013】

【数1】

$$\left( \frac{n^2 - 1}{n^2 + 2} \right) = \sum_{i=1}^N m_{(i)} \times \left( \frac{n_{(i)}^2 - 1}{n_{(i)}^2 + 2} \right) \times \frac{\rho}{\rho_{(i)}}$$

【0014】となる。但し、

【0015】

【数2】

$n_{(i)}$  :  $i$  番目の物質の屈折率、  
 $m_{(i)}$  :  $i$  番目の物質の重量分率、  
 $\rho_{(i)}$  :  $i$  番目の物質の密度、

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【0016】である。例えば液体を水溶液とすると、この水溶液の屈折率が水溶液自体の濃度に応じて変化するため、水溶液へ添加する物質の濃度を増減させれば良い。これにより、投影光学系の結像性能を補償できる屈折率の値となるように、液体の屈折率を変化させれば、投影光学系の結像性能は良好なものとなる。

【0017】ここで、屈折率の調整は、例えば投影光学系の収差などの結像性能を測定し、その結果に応じて屈折率を調整しても良く、投影光学系の結像性能の変動に対応している要因の変動を検知して、その結果に応じて屈折率を調整しても良い。前者の投影光学系の結像性能を測定する手法においては、露光装置の製造時に投影光学系の収差などを測定し、この収差を補償する屈折率の値を液体の屈折率の初期値に設定しても良い。このように製造時の調整の一部として屈折率を調整すれば、製造・調整が容易となる利点がある。また、露光装置自体に収差測定機構などを設けておき、この収差測定機構による収差測定結果に応じて、液体の屈折率を変更しても良い。

【0018】一方、後者の結像性能の変動に対応する要因の変動としては、レチクルの種類、照明条件の状態、投影光学系を通過する露光エネルギー量などが挙げられる。ここで、レチクルを照明する際の照明条件（α値、変形照明か否かなど）は、レチクル上に設けられるパターンの種類によって最適なものが決まり、この照明条件が変わると、投影光学系の収差を初めとする結像性能が変化する。そこで、例えばレチクルの種類、照明条件などの要因ごとに、この要因の変動に伴って変化する結像性能を補償するための屈折率の値を予めメモリなどに記憶させておき、この要因の変動を検知し、記憶された関係に基づいて液体の屈折率を調整すれば良い。また、投影光学系を通過する露光エネルギー量の大小により投影光学系の結像性能が変化する、いわゆる照射変動があるが、この場合においても、露光エネルギー量と、この露光エネルギー量の大小によって変化する結像性能を補償するための屈折率の値を予めメモリなどに記憶させておき、この要因の変動を検知し、記憶された関係に基づいて液体の屈折率を調整すれば良い。なお、この手法において、メモリに記憶させる代わりに、所定の計算式で算出しても良い。

【0019】このように、液体の屈折率を調整することで、投影光学系の結像性能のうち、特に球面収差、像面湾曲の補正に効果的である。以下、図面を参照して、本発明にかかる実施の形態について説明する。

【第1の実施の形態】図1は、本発明にかかる第1の実施の形態による露光装置を概略的に示す図である。尚、図1では、XYZ座標系を採用している。

【0020】図1において、光源Sは、例えば波長248nmの露光光を供給し、この光源Sからの露光光は、照明光学系1L及び反射鏡Mを介してレチクルRをほぼ

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均一な照度分布のもとで照明する。ここで、本例では光源Sとして、KrFエキシマレーザ光源を用いているが、その代わりに、193nmの露光光を供給するArFエキシマレーザ光源やg線、i線を供給する高圧水銀ランプ等を用いても良い。また、図1では不図示ではあるが照明光学系1Lは、面光源を形成するためのオブティカルインテグレータと、この面光源からの光を集光して被照射面を重畳的に均一照明するためのコンデンサ光学系と、オブティカルインテグレータにより形成される面光源の位置に配置されて面光源の形状を変化させるための可変開口絞りとを有するものである。ここで、面光源の形状としては、光軸から偏心した複数の面光源を持つもの、輪帯形状のもの、円形状であってその大きさがことなるものなどがある。このような照明光学系1Lとしては、例えば米国特許第5,329,094号公報や米国特許第5,576,801号公報に開示されているものを用いることができる。

【0021】そして、レチクルRを通過・回折した露光光は、投影光学系Tを経てウエハW上に達し、ウエハ上には、レチクルRの像が形成される。ここで、レチクルRは、レチクルローダーRLによって保持され、レチクルローダーRLは任意の時にローダーテーブルLT上を駆動装置T1により、X軸及びY軸上で任意の速度で移動できるように構成されている。ここで、レチクルローダーRLのローダーテーブルLT上での移動速度は、速度センサーSSで検知され、この速度センサーSSからの出力は、第1制御部CPU1へ伝達される。

【0022】また、ウエハWは、ウエハテーブルWTにより保持されている。このウエハテーブルWTには、液体LQを溜めるための側壁が設けられている。本例では、この側壁により、ウエハWから投影光学系Tまでの光路の全てが液体LQで満たされる構成となっている。このウエハテーブルWTは、駆動装置T2によりホルダーテーブルHT上でX軸方向及びY軸方向に任意の速度で移動できるように構成されている。

【0023】ここで、上記の第1制御部CPU1は、レチクルローダーRLのローダーテーブルLT上での移動速度と、投影光学系Tの露光倍率βとからウエハテーブルWTのホルダーテーブル上での移動速度を算出し、駆動装置T2へ伝達する。駆動装置は、第1制御部CPU1から伝達された移動速度に基づいて、ウエハテーブルWTを移動させる。

【0024】図2は、このウエハテーブルWTの構成を詳細に表した図である。この図2において、投影光学系Tの最もウエハW側の光学部材と、投影光学系Tの金枠との間は、液体LQが浸透してこないように密着しているか、パッキングされている。また、ウエハテーブルWTの底部には、複数の開口が設けられており、これらの開口に接続されている配管Vから減圧することにより、ウエハWはウエハテーブルWTに吸着されている。そし

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て、ウェハテーブルWTには、電極D1、D2が設けられており、これらの電極D1、D2のそれぞれの周囲には、イオン交換膜11、12が設けられている。これらのイオン交換膜11、12により、電極D1、D2の周囲と、露光光が液体LQを通過する領域とが区切られる。ここで、電極D1の周囲の雰囲気はイオン交換膜11と隔壁K1とにより密閉空間となっており、この密閉空間には排気管H1が接続されている。また、電極D2の周囲の雰囲気はイオン交換膜12と隔壁K2とにより密閉空間となっており、この密閉空間には排気管H2が接続されている。これらの排気管H1、H2は、ともに混合器Kに接続されている。この混合器Kには、電磁弁DVを備えた導入管LDの一端が接続されており、この導入管LDの他端は、ウェハテーブルWTの近傍に位置している。

【0025】電極D1、D2への印可電圧は図示なき電源供給部から供給され、電源供給部が供給する印可電圧は、第2制御部CPU2により制御される。また、電磁弁DVの開閉に関しても、第2制御部CPU2が制御する。本例では、これらの電極D1、D2、イオン交換膜11、12、隔壁K1、K2、排気管H1、H2、混合器K、電磁弁DV、導入管LD、図示なき電源供給部、第2制御部CPU2が屈折率調整手段を構成している。

【0026】以下、屈折率調整手段の動作について説明する。以下の説明において、液体LQは、純水に添加剤として塩化水系を加えたものであるとしている。まず、液体LQの屈折率を下げる場合、第2制御部CPU2は、電源供給部へ指令を送り、電極D1及び電極D2の間に所定の電圧を所定の時間だけ加印する。このとき、陽極となる電極からは酸素気体が発生し、陰極となる電極からは水系と塩素との混合気体が発生する。このとき、液体LQにおける塩化水系濃度が下がるため、上記(1)式からもわかるように、液体LQの屈折率が低下する。ここで、各々の電極D1、D2の近傍で発生した気体は、イオン交換膜11、12を通過しないため、排気管H1、H2を介して回収することが可能である。この回収された気体は、混合器Kへ送られる。混合器Kでは、回収された気体（酸素気体、水系気体、塩化水系気体）が混ぜ合わせられ、これより、液体LQよりも高濃度の添加物水溶液が生成される。

【0027】また、液体LQの屈折率を上げる場合、第2制御部CPU2は、電磁弁DVを開いて高濃度の添加物水溶液を液体LQへ加えるように、電磁弁DVへ指令を送る。これにより、液体LQの屈折率が上昇する。この構成により、液体LQの屈折率を可変にできる。さて、第2制御部CPU2に接続されているメモリーM1には、種々の照明条件ごとに対応して屈折率の値がテーブルの形で記憶されている。ここで、屈折率の値は、ある照明条件下において投影光学系Tで生じる収差を矯正

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するために必要な液体LQの屈折率の値である。また、このメモリーM1には、ある時点における液体LQ中の添加物濃度の値が、常に更新される形で保管されている。

【0028】また、上記の照明光学系1Lは、この照明光学系1Lが形成する面光露の形状に関する情報を第2制御部CPU2へ伝達するために、第2制御部CPU2と接続されている。ここで、照明条件-本例では面光源の形状-が変化すると、この情報は第2制御部CPU2へ伝達される。このとき、第2制御部CPU2は、伝達された照明条件に対応する屈折率の値をメモリーM1から検索し、その屈折率を実現するための添加物の濃度を上記(1)式から計算する。次に第2制御部CPU2は、メモリーM1に保管されている現在の添加物濃度と、計算された添加物濃度とに従って、現在の添加物濃度を計算された添加物濃度とするように、電極D1、D2あるいは電磁弁DVを制御する。

【0029】これにより、液体LQの屈折率の値は、液体LQを含めたときの投影光学系Tの収差が矯正されるものとなる。

【第2の実施の形態】第2の実施の形態は、第1の実施の形態における添加物をエチルアルコールとした点が大きく異なる。このエチルアルコールは、感光性基膜としてのレジストが塗布されたウェハWのレジスト層を溶解せず、投影光学系Tにおける最もウェハW側の光学部材（液体LQと接する光学部材）及びこの光学部材に施された光学コートへの影響が少ない利点がある。

【0030】また、第2の実施の形態においては、屈折率調整手段の構成が第1の実施の形態のものとは異なる。以下、図3を参照して屈折率調整手段の構成につき説明する。なお、図3において、図2に示したものと同一機能を有する部材には、同じ符号を付してある。第2の実施の形態によるウェハテーブルWTを示す図3において、第1の実施の形態のものとは異なる点は、添加物を液体LQへ供給するための添加物供給管LSと、純水を液体LQへ供給するための純水供給管WSと、液体LQがウェハテーブルWTから溢れないように液体LQを排出する排出管Lとを有する点である。

【0031】ここで、添加物供給管LS、純水供給管WS及び排出管Lには、添加物及び純水の供給量を調整するための電磁弁DVL S、DVWS及び液体LQの排出量を調整するための電磁弁DVL Lがそれぞれ設けられており、これらの電磁弁DVL S、DVWS、DVL Lの開閉は、第2制御部CPU2により制御されている。第2の実施の形態における屈折率調整時の動作について説明する。

【0032】まず、液体LQの屈折率を上げる場合、第2制御部CPU2は電磁弁DVL Sを制御して、所定の量だけ添加物を液体LQへ加える。このとき、排出管Lから液体LQを所定の量だけ排出する。この排出する液



光学系Tの最もウエハ面側の光学部材とウエハWとの間には、液体LQが介在している。投影光学系Tは、この液体LQを介してウエハ面上にレチクルRの縮小像を形成する。ウエハWは、ウエハテーブルWTに吸着固定されており、このウエハテーブルWTは、ウエハテーブルWT自体のZ軸方向への移動やティルト（Z軸に対する傾き）を行わせるためのZアクチュエータZD1、ZD2、ZD3を介して、定盤に対してXY方向に移動可能なウエハステージWTSに取り付けられている。このウエハステージWTSは、ウエハステージ駆動ユニットWDにより駆動される。また、ウエハテーブルの側壁は鏡面加工が施されており、この部分がウエハ干渉計WIの移動鏡となっている。ここで、ウエハステージ駆動ユニットWDの駆動は上述の第1制御部CPU1で制御され、ウエハ干渉計WIからの出力は第1制御部CPU1へ伝達される構成となっている。

【0042】また、投影光学系Tには、投影光学系TとウエハWとの間のZ方向の距離を測定するためのフォーカスセンサAFが設けられている。このフォーカスセンサAFは、投影光学系TにおけるウエハW側に近い光学系Tを介してウエハ面上に光を照射し、かつウエハで反射された光を上記光学系Tを介して受光し、その受光位置により投影光学系TとウエハWとの間のZ方向の距離を測定するものである。このようなフォーカスセンサAFの構成は、例えば特開平6-66543号公報に開示されている。

【0043】さて、第3の実施の形態においても、添加物保管部LSに貯蔵される高濃度の添加物水溶液を液体LQへ供給するための添加物供給管LSと、純水保管部WSTに貯蔵される純水を液体LQへ供給するための純水供給管WSとを備えており、添加物供給管LS及び純水供給管WSには、添加物水溶液及び純水の供給量を調整するための電磁弁DVLS、DVWSが設けられている。また、ウエハテーブルWTには、液体LQがウエハテーブルから溢れないように液体LQを排出するための排出管Lが設けられており、この排出管Lには、液体LQの排出量を調整するための電磁弁が設けられている。これらの電磁弁DVLS、DVWS、DVLの開閉は、上述の第2の実施の形態と同様に、第2制御部CPU2により制御されている。

【0044】また、ウエハテーブルWT上には、投影光学系Tの収差を測定するための収差測定部ASと、液体LQの添加物濃度を検出するための添加物濃度検出部DSとが設けられている。ここで、収差測定部ASとしては、例えば特開平6-84757号公報に開示されているものを用いることができる。ここで、収差測定部AS及び添加物濃度検出部DSからの出力は、第2制御部CPU2へ伝達される。また、添加物濃度検出部DSからの出力は、第2制御部CPU2を介してメモリーM1へある時点における液体LQの添加物濃度の値として保管され

る。

【0045】次に、第3の実施の形態の動作について説明する。まず、図示なきレチクルストッカーからレチクルRが取り出されてレチクルローダーRL上に設置される途中に、バーコードリーダーBRは、レチクルRに設けられているバーコードを読み取り、その情報を第2制御部CPU2へ伝達する。第2制御部CPU2は、メモリーM1に記憶されているレチクルRの種類に対応した照明条件に関する情報を読み出し、その情報に従って、可変開口絞り駆動ユニット17を制御して開口絞り16a~16fのうちの所定の一つを光路内に位置させる。また、第2制御部CPU2は、メモリーM1に記憶されている液体LQの屈折率の値に基づいて、その屈折率を実現するための添加物濃度を上記(1)式から計算する。その後、添加物濃度検出部DSにより検出されてメモリーM1に保管されている現在の添加物濃度と、計算された添加物濃度とに従って、現在の添加物濃度を計算された添加物濃度とするように、電磁弁DVLS、DVWS、DVLの開閉を制御する。

【0046】これにより、液体LQの屈折率の値は、液体LQを含めたときの投影光学系Tの収差が補正されるものとなる。この後、フォーカスセンサAFによりウエハWのZ方向の位置及びティルトを検出して、ウエハWが所望の位置になるようにZアクチュエータZD1、ZD2、ZD3を駆動する。この状態において、光源Sからの露光光を照明光学系を介してレチクルRへ導き、第1制御部CPU1は、レチクル干渉計RI及びウエハ干渉計WIによりレチクルR及びウエハWの位置を検出しつつ、レチクルローダー駆動ユニットRLD及びウエハステージ駆動ユニットWDを駆動させ、レチクルR及びウエハWを投影光学系Tの投影倍率 $\beta$ 1の速度比の元で移動させる。これにより、レチクルR上のパターンは、良好な結像状態のもとでウエハW上へ転写される。

【0047】さて、投影光学系Tの結像性能（収差など）は、常に一定ではなく、温度変化や大気圧変化、投影光学系Tが露光光を吸収することによる温度上昇などにより変化する場合がある。そこで、第3の実施の形態では、収差測定部ASにより実際の投影光学系Tの収差（結像性能）を測定し、この測定結果に基づいて液体LQの屈折率の値を調整する構成としている。

【0048】具体的には、第3の実施の形態では、メモリーM1内に投影光学系Tの収差値に対応させた形で、その収差を補正できる液体LQの屈折率の値が記憶されている。そして、収差測定部ASにより検出された投影光学系Tの収差は、第2制御部CPU2へ伝達される。第2制御部CPU2は、メモリーM1内に記憶されている液体LQの屈折率の値を読み出し、この屈折率の値になるように添加物濃度を上記(1)式より求め、液体LQがその添加物濃度となるように電磁弁DVLS、DVWS、DVLの開閉を制御する。







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**DETAILED DESCRIPTION**


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[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] this invention relates to the exposure method and the device manufacture method using an aligner and this aligner equipped with the projection optical system which projects the device pattern's prepared on the reticle on a photosensitive substrate. this invention relates to the immersed type aligner which filled up the optical path between a projection optical system and a photosensitive substrate with the liquid in more detail. In case this invention manufactures a semiconductor device, image pck-up elements (CCD etc.), a liquid crystal display element, or the thin film magnetic head, it is suitable.

[0002]

[Description of the Prior Art] Although the space between the last side of optical system and the image surface was called working distance, the working distance was filled with air at the projection optical system of the conventional aligner. By the way, the detailed-ization is always desired, and the pattern exposed to a silicon wafer in process in which IC and LSI are manufactured needs to shorten wavelength of the light which for that is used for exposure, or needs to enlarge numerical aperture by the side of an image. The glass material only with the permeability which can secure the quantity of light satisfied with exposure decreases obtaining a satisfying image formation performance as the wavelength of light becomes short.

[0003] Then, the aligner in which enlarging numerical aperture by the side of an image by using the last medium to the image surface as a liquid with a larger refractive index than air is proposed, and it has a projection optical system using the liquid such is called immersed type aligner. Now, in the aligner, the technology in which a projection optical system prepares the image formation performance of a projection optical system in an amendment sake the most possible [ exchange of the optical path by the side of a body or the image formation performance amendment member for adjusting an image formation performance into the optical path by the side of an image most ] is known.

[0004]

[Problem(s) to be Solved by the Invention] However, in an immersed type aligner, since it is the composition of filling a liquid to the optical path between a projection optical system and a photosensitive substrate (working distance), it is difficult to arrange the member of an amendment sake for an image formation performance. Moreover, since considering the composition of a limited number and realistic equipment such an image formation performance amendment member can prepare only a grade partly, it has the trouble which cannot amend a dispersed image formation performance.

[0005] Moreover, although it is necessary to store the image formation performance of a projection optical system in predetermined tolerance, if amendment of an image formation performance cannot be performed dispersedly as mentioned above, storing in this predetermined tolerance becomes difficult. If detailed-izing of an exposure pattern and increase of exposure area are called for especially, when performing the scanning exposure method exposed the tolerance of this image formation performance becoming narrow, and making a reticle and a photosensitive substrate scan, the tolerance of the range of

fluctuation of an image formation performance characteristic is narrow, and cannot respond in dispersed amendment.

[0006] moreover, the above image formation performance amendments -- since vibration of the projection optical system itself occurs at the time of exchange of a member, there is also a possibility that a bad influence may arise to an image formation performance. Then, this invention sets it as the 1st purpose to enable amendment of a continuous image formation performance, without being accompanied by vibration. moreover, this invention -- increase and the image formation performance of the numerical aperture of a projection optical system -- an amendment -- coexistence with things is set as the 2nd purpose

[0007]

[Means for Solving the Problem] the aligner according to this invention in order to attain the 1st above-mentioned purpose has the lighting optical system which illuminates the pattern prepared on the reticle, and the projection optical system which form the image of this pattern on a photosensitive substrate, is the aligner exposed through the liquid which a part is boiled in the optical path between a projection optical system and a photosensitive substrate at least, and is located, and has a refractive-index adjustment means for adjusting the refractive index of a liquid

[0008] according to the desirable mode hung up over the above-mentioned claim 2 here -- a refractive-index adjustment means -- the image formation performance of the aforementioned projection optical system -- an amendment -- the refractive index of a liquid is adjusted like what is further equipped with an image formation performance-measurement means to measure the image formation performance of a projection optical system according to the desirable mode hung up over the claim 3 based on this composition -- it is -- a refractive-index adjustment means -- the aforementioned image formation performance -- an amendment -- the refractive index of a liquid is adjusted like

[0009] moreover, the thing which is further equipped with a change factor detection means to detect the state of the factor of change of the image formation performance of a projection optical system according to the desirable mode hung up over the claim 4 -- it is -- a refractive-index adjustment means -- the state of a factor -- responding -- an image formation performance -- an amendment -- the refractive index of a liquid is adjusted like according to the desirable mode hung up over the claim 5 based on this composition, lighting optical system is constituted possible [ change of the lighting conditions over the aforementioned reticle ] -- having -- a change factor detection means -- the state of lighting conditions -- detecting -- a refractive-index adjustment means -- change of lighting conditions -- responding -- an image formation performance -- an amendment -- the refractive index of a liquid is adjusted like

[0010] and the thing from which a change factor detection means distinguishes the kind of reticle according to the desirable mode hung up over the claim 6 -- it is -- a refractive-index adjustment means -- the kind of reticle -- responding -- an image formation performance -- an amendment -- the refractive index of a liquid is adjusted like Moreover, in order to attain the 2nd above-mentioned purpose, it is desirable to fill all the optical paths between a projection optical system and a photosensitive substrate with a liquid. As for the aligner by this invention, at this time, it is desirable to have further the photosensitive substrate electrode holder which is equipped with the side attachment wall for filling the optical path between a projection optical system and a photosensitive substrate with the aforementioned liquid and supply / recovery unit for collecting from the aforementioned photosensitive substrate electrode holder while supplying a liquid to the aforementioned photosensitive substrate electrode holder, and holds a photosensitive substrate.

[0011] Moreover, as for a refractive-index adjustment means, it is desirable to have the additive supply unit which supplies the additive for adjusting a refractive index to a liquid, and an additive recovery unit for collecting the aforementioned additives from a liquid.

[0012]

[Embodiments of the Invention] since the refractive index of the liquid located in the optical path between a projection optical system and a photosensitive substrate can be adjusted in this invention like above-mentioned composition -- change of this refractive index -- the image formation performance of a projection optical system -- an amendment -- things are made As the technique of refractive-index

adjustment here, supposing a liquid is a multi-intermixing-of-material liquid, the refractive index  $n$  of this mixed liquor object will follow the formula of Lorentz Lawrence (Lorentz-Lorenz), and it is [0013].  
[Equation 1]

$$\left( \frac{n^2 - 1}{n^2 + 2} \right) = \sum_{i=1,2,\dots} m_{(i)} \times \left( \frac{n_{(i)}^2 - 1}{n_{(i)}^2 + 2} \right) \times \frac{\rho}{\rho_{(i)}}$$

[0014] It becomes. However, [0015]

[Equation 2]

$n_{(i)}$  :  $i$  番目の物質の屈折率、  
 $m_{(i)}$  :  $i$  番目の物質の重量分率、  
 $\rho_{(i)}$  :  $i$  番目の物質の密度、

[0016] It comes out. For example, what is necessary is just to make the concentration of the matter added to solution fluctuate, since the refractive index of this solution will change according to the concentration of solution itself, if a liquid is made into solution. If the refractive index of a liquid is changed so that this may become the value of the refractive index which can compensate the image formation performance of a projection optical system, the image formation performance of a projection optical system will become good.

[0017] Here, adjustment of a refractive index may measure image formation performances, such as aberration of a projection optical system, may adjust a refractive index according to the result, may detect the change of a factor corresponding to change of the image formation performance of a projection optical system, and may adjust a refractive index according to the result. In the technique of measuring the image formation performance of the former projection optical system, the aberration of a projection optical system etc. may be measured at the time of manufacture of an aligner, and the value of the refractive index which compensates this aberration may be set as the initial value of the refractive index of a liquid. Thus, if a refractive index is adjusted as a part of adjustment at the time of manufacture, there is an advantage from which manufacture and adjustment become easy. Moreover, the aberration measurement mechanism etc. is prepared in the aligner itself, and the refractive index of a liquid may be changed according to the aberration measurement result by this aberration measurement mechanism.

[0018] On the other hand, as change of the factor corresponding to change of the latter image formation performance, the amount of exposure energy which passes the kind of reticle, the state of lighting conditions, and a projection optical system is mentioned. here, if the optimal thing is decided by the kind of pattern established on a reticle and lighting conditions at the time of illuminating a reticle, such as etc., a sigma value and deformation lighting \*\*\*\*\* -- change this lighting condition according to it, the image formation performance which makes aberration of a projection optical system the start will change What is necessary is to make memory etc. memorize beforehand the value of the refractive index for compensating the image formation performance which changes with change of this factor for every factors, such as a kind of reticle, and lighting conditions, to detect change of this factor and just to adjust the refractive index of a liquid there based on the memorized relation. Moreover, although there is the so-called irradiation change from which the image formation performance of a projection optical system changes with the size of the amount of exposure energy which passes a projection optical system Also in this case, what is necessary is to make memory etc. memorize beforehand the value of the refractive index for compensating the image formation performance which changes with the size of the amount of exposure energy, and this amount of exposure energy, to detect change of this factor and just to adjust the refractive index of a liquid based on the memorized relation. In addition, in this technique, you may compute in a predetermined formula instead of making memory memorize.

[0019] Thus, it is effective for especially amendment of spherical aberration and a curvature of field among the image formation performances of a projection optical system by adjusting the refractive

index of a liquid. Hereafter, the gestalt of operation concerning this invention is explained with reference to a drawing.

[Gestalt of the 1st operation] drawing 1 is drawing showing roughly the aligner by the gestalt of the 1st operation concerning this invention. In addition, XYZ system of coordinates are adopted in drawing 1. [0020] In drawing 1, the light source S supplies exposure light with a wavelength of 248nm, and the exposure light from this light source S illuminates Reticle R under an almost uniform illumination distribution through the lighting optical system IL and a reflecting mirror M. Here, in this example, as the light source S, although the KrF excimer laser is used instead, you may use the high-pressure mercury lamp which supplies the ArF excimer laser which supplies 193nm exposure light, g line, i line, etc. Moreover, in drawing 1, although not illustrated, the lighting optical system IL has the optical integrator for forming the surface light source, the capacitor optical system for condensing the light from this surface light source, and carrying out uniform lighting of the irradiated plane in superposition, and an adjustable aperture diaphragm for being arranged in the position of the surface light source formed by the optical integrator, and making the configuration of the surface light source adjustable. what has two or more surface light sources which carried out eccentricity from the optical axis as a configuration of the surface light source here, the thing of a zona-orbicularis configuration, and a circle configuration -- it is -- the size -- things -- there is a thing etc. As such lighting optical system IL, what is indicated by the U.S. Pat. No. 5,329,094 official report and the U.S. Pat. No. 5,576,801 official report, for example can be used.

[0021] And the exposure light which passed and diffracted Reticle R reaches on Wafer W through a projection optical system T, and the image of Reticle R is formed on a wafer. Here, Reticle R is held by the reticle loader RL, and the reticle loader RL is constituted so that it can move at arbitrary speed on the X-axis and a Y-axis with a driving gear T1 in the loader table LT top at the arbitrary times. Here, the traverse speed on the loader table LT of a reticle loader RL is detected by the speed sensor SS, and the output from this speed sensor SS is transmitted to the 1st control section CPU 1.

[0022] Moreover, Wafer W is held on the wafer table WT. The side attachment wall for collecting Liquids LQ is prepared in this wafer table WT. In this example, it has the composition that all the optical paths from Wafer W to a projection optical system T are filled with Liquid LQ, by this side attachment wall. This wafer table WT is constituted so that it can move to X shaft orientations and Y shaft orientations at arbitrary speed on the electrode-holder table HT with a driving gear T2.

[0023] Here, the 1st above-mentioned control section CPU 1 computes the traverse speed on the electrode-holder table of the wafer table WT from the exposure scale factor beta of a projection optical system T, and delivers it the traverse speed on the loader table LT of a reticle loader RL to a driving gear T2. A driving gear moves the wafer table WT based on the traverse speed transmitted from the 1st control section CPU 1.

[0024] Drawing 2 is drawing which expressed the composition of this wafer table WT in detail. this drawing 2 -- setting -- a projection optical system T -- most, between the optical member by the side of Wafer W, and the metal flask of a projection optical system T, it has stuck so that Liquid LQ may not permeate, or packing is carried out Moreover, two or more openings are prepared in the pars basilaris ossis occipitalis of the wafer table WT, and Wafer W is adsorbed by the wafer table WT by decompressing from the piping V connected to these openings. And electrodes D1 and D2 are formed in the wafer table WT, and ion exchange membrane I1 and I2 is formed in each circumference of these electrodes D1 and D2. The circumference of electrodes D1 and D2 and the field where exposure light passes Liquid LQ are divided by such ion exchange membrane I1 and I2. Here, the atmosphere around an electrode D1 serves as a closed space by ion exchange membrane I1 and the septum K1, and the exhaust pipe H1 is connected to this closed space. Moreover, the atmosphere around an electrode D2 serves as a closed space by ion exchange membrane I2 and the septum K2, and the exhaust pipe H2 is connected to this closed space. Both these exhaust pipes H1 and H2 are connected to Mixer K. The end of the introductory pipe LD equipped with the solenoid valve DV is connected to this mixer K, and the other end of this introductory pipe LD is located near the wafer table WT.

[0025] The seal-of-approval voltage which the seal-of-approval voltage to electrodes D1 and D2 is

supplied from the current supply section without illustration, and the current supply section supplies is controlled by the 2nd control section CPU 2. Moreover, \*\* and the 2nd control section CPU 2 control also about opening and closing of a solenoid valve DV. These electrodes D1 and D2, ion exchange membrane I1 and I2, septa K1 and K2, exhaust pipes H1 and H2, Mixer K, a solenoid valve DV, the introductory pipe LD, the current supply section without illustration, and the 2nd control section CPU 2 constitute the refractive-index adjustment means from this example.

[0026] Hereafter, operation of a refractive-index adjustment means is explained. In the following explanation, Liquid LQ supposes that a hydrogen chloride is added to pure water as an additive. First, when lowering the refractive index of Liquid LQ, the 2nd control section CPU 2 sends instructions to the current supply section, and only predetermined time carries out the \*\* mark of the predetermined voltage between an electrode D1 and an electrode D2. At this time, an oxygen gas occurs from the electrode used as an anode plate, and the mixture of gas of hydrogen and chlorine occurs from the electrode used as cathode. Since the hydrogen chloride concentration in Liquid LQ falls at this time, as shown also in the above-mentioned (1) formula, the refractive index of Liquid LQ falls. Since the gas generated near each electrodes D1 and D2 does not pass ion exchange membrane I1 and I2, it can be collected through exhaust pipes H1 and H2 here. This collected gas is sent to Mixer K. In Mixer K, the collected gas (an oxygen gas, a hydrogen gas, hydrogen chloride gas) is mixed, and the additive solution of high concentration [ Liquid / LQ ] is generated from this.

[0027] Moreover, when gathering the refractive index of Liquid LQ, the 2nd control section CPU 2 sends instructions to a solenoid valve DV so that a solenoid valve DV may be opened and high-concentration additive solution may be added to Liquid LQ. Thereby, the refractive index of Liquid LQ rises. By this composition, the refractive index of Liquid LQ is made to adjustable. Now, it corresponds to the memory M1 connected to the 2nd control section CPU 2 for every various lighting conditions, and the value of a refractive index is memorized in the form of a table. Here, the value of a refractive index is a value of the refractive index of the liquid LQ required for an amendment sake about the aberration produced in a projection optical system T under a certain lighting condition. Moreover, the value of the additive concentration in the liquid LQ at a certain time is kept by this memory M1 in the form always updated.

[0028] Moreover, the above-mentioned lighting optical system IL is connected with the 2nd control section CPU 2 in order to transmit the information about the configuration of the surface light source which this lighting optical system IL forms to the 2nd control section CPU 2. Here, in the example of a lighting condition-book, change of configuration - of the surface light source transmits this information to the 2nd control section CPU 2. At this time, the 2nd control section CPU 2 searches the value of the refractive index corresponding to the transmitted lighting conditions from memory M1, and calculates the concentration of the additive for realizing the refractive index from the above-mentioned (1) formula. Next, the 2nd control section CPU 2 controls electrodes D1 and D2 or a solenoid valve DV according to the present additive concentration currently kept by memory M1 and the calculated additive concentration to consider as the additive concentration which had the present additive concentration calculated.

[0029] Thereby, the aberration of the projection optical system T when the value of the refractive index of Liquid LQ includes Liquid LQ is amended.

It differs greatly in that the form of [form of the 2nd operation] the 2nd operation made the additive in the form of the 1st operation ethyl alcohol. This ethyl alcohol does not dissolve the resist layer of the wafer W with which the resist as a photosensitive substrate was applied, but has an advantage with little influence on the optical coat in a projection optical system T most given to the optical member (optical member which touches Liquid LQ) and this optical member by the side of Wafer W.

[0030] Moreover, in the form of the 2nd operation, the composition of a refractive-index adjustment means differs from the thing of the form of the 1st operation. Hereafter, with reference to drawing 3, it explains per composition of a refractive-index adjustment means. In addition, in drawing 3, the same sign is given to the member which has the same function as what was shown in drawing 2. In drawing 3 which shows the wafer table WT by the form of the 2nd operation, the thing of the form of the 1st

operation is the point of having the exhaust pipe L which discharges Liquid LQ so that the pure water supply pipe WS and Liquid LQ for supplying the additive supply pipe LS and pure water for a different point supplying an additive to Liquid LQ to Liquid LQ may not overflow from the wafer table WT.

[0031] Here, the solenoid valve DVL for adjusting the solenoid valves DVLS and DVWS for adjusting the amount of supply of an additive and pure water and the discharge of Liquid LQ to the additive supply pipe LS, the pure water supply pipe WS, and an exhaust pipe L is formed, respectively, and opening and closing of these solenoid valves DVLS, DVWS, and DVL are controlled by the 2nd control section CPU 2. Operation at the time of the refractive-index adjustment in the form of the 2nd operation is explained.

[0032] First, when gathering the refractive index of Liquid LQ, a solenoid valve DVLS is controlled and, as for the 2nd control section CPU 2, only a predetermined amount adds an additive to Liquid LQ. At this time, only a predetermined amount discharges Liquid LQ from an exhaust pipe L. As for the amount of this liquid LQ to discharge, it is desirable that it is the same as the amount of the added additive. Thereby, the additive concentration in Liquid LQ increases and the refractive index rises.

[0033] Moreover, when lowering the refractive index of Liquid LQ, a solenoid valve DVWS is controlled and, as for the 2nd control section CPU 2, only a predetermined amount adds pure water to Liquid LQ. At this time, only a predetermined amount discharges Liquid LQ from an exhaust pipe L. As for the amount of this liquid LQ to discharge, it is desirable that it is the same as the amount of the added pure water. Thereby, the additive concentration in Liquid LQ becomes low, and the refractive index falls.

[0034] Here, the amount of the additive added and pure water and the amount of the liquid LQ to discharge are controlled by the 2nd control section CPU 2. In addition, the point that the value of a refractive index is memorized in memory M1 corresponding to the kind of lighting conditions, and the point that the value of the additive concentration of the liquid LQ at a certain time is kept are the same as the form of the 1st operation of a \*\*\*\*\*, and are the same as the form of operation of the point 1st which calculates the additive concentration for realizing the refractive index which can amend the aberration of a projection optical system T based on these information.

[0035] Thus, the 2nd control section CPU 2 in the form of the 2nd operation controls opening and closing of solenoid valves DVLS, DVWS, and DVL to consider as the additive concentration which had the present additive concentration calculated according to the present additive concentration currently kept by memory M1 and the calculated additive concentration. Thereby, the aberration of the projection optical system T when the value of the refractive index of Liquid LQ includes Liquid LQ is amended. The form of the 3rd operation is explained with reference to [the form of the 3rd operation], next drawing 4. The aligner by the form of the 3rd operation differs from the form of the above-mentioned 1st and the 2nd above-mentioned operation at a point equipped with the aberration measuring device. In addition, in drawing 4, the same sign is given to the member which has the same function as the example of above-mentioned drawing 1 - drawing 3, and the same XYZ system of coordinates as drawing 1 are adopted.

[0036] In drawing 4, the light source S supplies exposure light with a wavelength of 248nm, and after the exposure light from this light source S is prepared by the cross section of a predetermined configuration with the beam plastic surgery optical system 11, it carries out incidence of it to the 1st fly eye lens 12. The secondary light source which consists of two or more light source images is formed in the injection side of the 1st fly eye lens 12. Incidence of the exposure light from this secondary light source is carried out to the 2nd fly eye lens 15 through the relay lens systems 13F and 13R. This relay lens system consists of pre-group 13F and back group 13R, and the oscillating mirror 14 for preventing the speckle on an irradiated plane is arranged among such pre-group 13F and back group 13R.

[0037] Now, two or more images of the secondary light source by the 1st fly eye lens are formed, and this serves as the 3rd light source at the injection side side of the 2nd fly eye lens 15. The adjustable aperture diaphragm 16 which can set up two or more aperture diaphragms which have a predetermined configuration or a predetermined, predetermined size in the position in which this 3rd light source is formed is arranged. This adjustable aperture diaphragm 16 forms six aperture diaphragms 16a-16e by



which patterning was carried out on the transparent substrate which consisted of quartzes etc. in the shape of a turret, as shown in drawing 5. Here, two aperture diaphragms 16a and 16b with circular opening are drawing for changing a sigma value (numerical aperture of the lighting optical system to the numerical aperture of a projection optical system), and two aperture diaphragms 16c and 16d with a \*\*\*\* configuration are drawing with which \*\*\*\* ratios differ mutually. And the two remaining aperture diaphragms 16e and 16f are drawing which has four openings which carried out eccentricity. By the adjustable aperture-diaphragm drive unit 17, this adjustable aperture diaphragm 16 is driven so that any or 1 of two or more aperture diaphragms 16a-16f may be located in an optical path.

[0038] Returning to drawing 4, it is condensed by the condensing lens system 18 and the exposure light from the adjustable aperture diaphragm 16 illuminates a reticle-blind 19 top in superposition. The reticle blind 19 is arranged about the relay optical system 20F and 20R at the pattern formation side of Reticle R, and conjugate, and the configuration of the lighting field on Reticle R is determined by the opening configuration of a reticle blind 19. The exposure light from a reticle blind 19 forms the lighting field of a uniform illumination distribution in the position on Reticle R substantially through back group 20R of pre-group 20F of relay optical system, a reflecting mirror M, and relay optical system.

[0039] In addition, the lighting optical system IL in the form of the above-mentioned 1st and the 2nd above-mentioned operation can also apply the beam plastic surgery optical system 11 shown in the form of this operation - the relay optical system 20F and 20R. Now, Reticle R is laid on the reticle loader RL, and this reticle loader RL can move it to the XY direction in drawing, and the hand of cut (the direction of theta) centering on the Z-axis on the electrode-holder table LT. The move mirror RIM is formed in this reticle loader RL, and the reticle interferometer RI detects the position of the XY direction of a reticle loader RL, and the direction of theta. Moreover, a reticle loader RL is driven in the XY direction and the direction of theta by the reticle-loader drive unit RLD. Here, the output from the reticle interferometer RI is transmitted to the 1st control section CPU 1, and the 1st control section CPU 1 has composition which controls the reticle-loader drive unit RLD.

[0040] Moreover, the bar code reader BR for reading the bar code prepared in Reticle R in the middle of the conveyance way from a reticle stocker without illustration is formed. The information about the kind of reticle R which this bar code reader BR read is transmitted to the 2nd control section CPU 2. Here, the value of the refractive index of the optimal liquid LQ is remembered to be the information about the optimal lighting conditions for every kind of reticle R for every kind of reticle R by the memory M1 connected to the 2nd control section CPU 2.

[0041] the projection optical system T which has predetermined reduction scale-factor  $|\beta|$  prepares in Reticle R bottom -- having -- \*\*\*\* -- this projection optical system T -- between the optical member by the side of a wafer side, and Wafer W, Liquid LQ intervenes most A projection optical system T forms the reduction image of Reticle R on a wafer side through this liquid LQ. Adsorption fixation of the wafer W is carried out at the wafer table WT, and this wafer table WT is attached in the wafer stage WTS movable in the XY direction to the surface plate through the Z actuators ZD1, ZD2, and ZD3 for making movement to Z shaft orientations of the wafer table WT itself, and a tilt (inclination to the Z-axis) perform. This wafer stage WTS is driven by the wafer stage drive unit WD. Moreover, mirror-plane processing is given and, as for the side attachment wall of a wafer table, this portion serves as a move mirror of the wafer interferometer WI. Here, the drive of the wafer stage drive unit WD is controlled by the 1st above-mentioned control section CPU 1, and the output from the wafer interferometer WI has composition transmitted to the 1st control section CPU 1.

[0042] Moreover, the focal sensor AF for measuring the distance of the Z direction between a projection optical system T and Wafer W is formed in the projection optical system T. This focal sensor AF receives the light which irradiated light on the wafer side through the optical element near the wafer W side in a projection optical system T, and was reflected with the wafer through the above-mentioned optical element, and measures the distance of the Z direction between a projection optical system T and Wafer W with the light-receiving position. The composition of such a focal sensor AF is indicated by JP,6-66543,A.

[0043] Now, also in the form of the 3rd operation, it has the pure water supply pipe WS for supplying

the pure water stored in the additive supply pipe LS and the pure water storage section WST for supplying the high-concentration additive solution stored in the additive storage section latest starting time to Liquid LQ to Liquid LQ, and the solenoid valves DVLS and DVWS for adjusting the amount of supply of additive solution and pure water are formed in the additive supply pipe LS and the pure water supply pipe WS. Moreover, the exhaust pipe L for discharging Liquid LQ is formed in the wafer table WT so that Liquid LQ may not overflow from a wafer table, and the solenoid valve for adjusting the discharge of Liquid LQ is prepared in this exhaust pipe L. Opening and closing of these solenoid valves DVLS, DVWS, and DVL are controlled by the 2nd control section CPU 2 like the form of the 2nd operation of a \*\*\*\*.

[0044] Moreover, on the wafer table WT, the additive concentration detecting element DS for detecting the additive concentration of the aberration test section AS for measuring the aberration of a projection optical system and Liquid LQ is formed. Here, as an aberration test section AS, what is indicated by JP,6-84757,A, for example can be used. Here, the output from the aberration test section AS and the additive concentration detecting element DS is transmitted to the 2nd control section CPU 2. Moreover, the output from the additive concentration detecting element DS minds the 2nd control section CPU 2, and is kept as a value of the additive concentration of the liquid LQ at a certain time to memory M1.

[0045] Next, operation of the form of the 3rd operation is explained. First, while Reticle R being taken out from a reticle stocker without illustration, and being laid on a reticle loader RL, a bar code reader BR reads the bar code prepared in Reticle R, and transmits the information to the 2nd control section CPU 2. The 2nd control section CPU 2 reads the information about the lighting conditions corresponding to the kind of reticle R memorized by memory M1, controls the adjustable aperture-diaphragm drive unit 17 according to the information, and locates one of aperture diaphragms 16a-16f predetermined in an optical path. Moreover, the 2nd control section CPU 2 calculates the concentration of the additive for realizing the refractive index from the above-mentioned (1) formula based on the value of the refractive index of the liquid LQ memorized by memory M1. Then, opening and closing of solenoid valves DVLS, DVWS, and DVL are controlled to consider as the additive concentration which had the present additive concentration calculated according to the present additive concentration which is detected by the additive concentration detecting element DS and kept by memory M1, and the calculated additive concentration.

[0046] Thereby, the aberration of the projection optical system T when the value of the refractive index of Liquid LQ includes Liquid LQ is amended. Then, the focal sensor AF detects the position and tilt of a Z direction of Wafer W, and the Z actuators ZD1, ZD2, and ZD3 are driven so that Wafer W may become a necessary position. In this state, the exposure light from the light source S is led to Reticle R through lighting optical system, and the 1st control section CPU 1 detecting the position of Reticle R and Wafer W with the reticle interferometer RI and the wafer interferometer WI, it makes the reticle-loader drive unit RLD and the wafer stage drive unit WD drive, and moves Reticle R and Wafer W under the velocity ratio of projection scale-factor  $|\beta|$  of a projection optical system T. Thereby, the pattern on Reticle R is imprinted on Wafer W under a good image formation state.

[0047] Now, the image formation performances (aberration etc.) of a projection optical system T always may not be fixed, and it may change with a temperature change, atmospheric pressure change, the temperature rises by a projection optical system T absorbing exposure light, etc. Then, with the form of the 3rd operation, the aberration (image formation performance) of the actual projection optical system T is measured by the aberration test section AS, and it is considering as the composition which adjusts the value of the refractive index of Liquid LQ based on this measurement result.

[0048] Specifically, with the form of the 3rd operation, it is the form where the aberration value of a projection optical system was made to correspond in memory M1, and the value of the refractive index of the liquid LQ which can amend the aberration is memorized. And the aberration of the projection optical system T detected by the aberration test section AS is transmitted to the 2nd control section CPU 2. The 2nd control section CPU 2 reads the value of the refractive index of the liquid LQ memorized in memory M1, it asks for additive concentration from the above-mentioned (1) formula so that it may become the value of this refractive index, and it controls opening and closing of solenoid valves DVLS,

DVWS, and DVL so that Liquid LQ serves as the additive concentration.

[0049] Even if there is an environmental variation (a temperature change, atmospheric pressure change, change by the exposure optical absorption) of a projection optical system T, the image formation performance is maintainable good with this composition. In addition, what is necessary is not to always perform measurement by this aberration test section AS, and just to perform it for every predetermined period.

[the form of the 4th operation] -- with reference to drawing 6, the form of the 4th operation is explained below. The form of the 4th operation is considered as the composition which fills a part of this optical path with a liquid instead of the composition which fills all the optical paths between a projection optical system and a wafer with a liquid.

[0050] In drawing 6 (a) and (b), the same sign is laid down on the member which has the 1st shown in drawing 1 -3, and the same function as the form of the 2nd operation. At the form of the 4th operation shown in drawing 6 (a) and (b), it is a wafer electrode holder. - The container C1 which consisted of material (for example, quartz etc.) which makes exposure light penetrate, and the composition which fills Liquid LQ in C2 differ from the form of the above-mentioned 1st and the 2nd above-mentioned operation instead of collecting Liquids LQ by the side attachment wall of WT. by this composition, among the effects which the form of the above-mentioned 1st and the 2nd above-mentioned operation had, although there is no effect of an efficiency depth of focus expansion, it has numerical-aperture increase or the effect whose aberration (image formation performance) adjustment of a projection optical system T is attained continuously.

[0051] In addition, in the gestalt of this 4th operation, you may form the containers C1 and C2 currently put into Liquid LQ in a projection optical system T and one. With the above gestalt of the 1st - the 4th operation, although pure water was used as a liquid LQ, it is not restricted to pure water.

[0052]

[Effect of the Invention] As shown above, according to this invention, the image formation performance of a projection optical system can be adjusted continuously without vibration. Moreover, it becomes possible to reconcile increase (or expansion of the efficiency-depth of focus) of numerical aperture, and adjustment of an image formation performance.

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[Translation done.]

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**CLAIMS**


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[Claim(s)]

[Claim 1] the aligner characterized by to have the lighting optical system which illuminates the pattern prepared on the reticle, and the projection optical system which forms the image of this pattern on a photosensitive substrate, and to have a refractive-index adjustment means for adjusting the refractive index of the aforementioned liquid in the aligner exposed through the liquid which a part is boiled in the optical path between the aforementioned projection optical system and the aforementioned photosensitive substrate at least, and is located

[Claim 2] the aforementioned refractive-index adjustment means -- the image formation performance of the aforementioned projection optical system -- an amendment -- the aligner according to claim 1 characterized by adjusting the refractive index of the aforementioned liquid like

[Claim 3] an image formation performance-measurement means to measure the image formation performance of the aforementioned projection optical system -- further -- having -- the aforementioned refractive-index adjustment means -- the aforementioned image formation performance -- an amendment -- the aligner according to claim 2 characterized by adjusting the refractive index of the aforementioned liquid like

[Claim 4] a change factor detection means to detect the state of the factor of change of the image formation performance of the aforementioned projection optical system -- further -- having -- the aforementioned refractive-index adjustment means -- the state of the aforementioned factor -- responding -- the aforementioned image formation performance -- an amendment -- the aligner according to claim 1 characterized by adjusting the refractive index of the aforementioned liquid like

[Claim 5] the aforementioned lighting optical system is constituted possible [ change of the lighting conditions over the aforementioned reticle ] -- having -- the aforementioned change factor detection means -- the state of the aforementioned lighting conditions -- detecting -- the aforementioned refractive-index adjustment means -- the change of the aforementioned lighting conditions -- responding -- the aforementioned image-formation performance -- an amendment -- the aligner according to claim 4 characterized by to adjust the refractive index of the aforementioned liquid like

[Claim 6] that from which the aforementioned change factor detection means distinguishes the kind of the aforementioned reticle -- it is -- the aforementioned refractive-index adjustment means -- the kind of the aforementioned reticle -- responding -- the aforementioned image formation performance -- an amendment -- the aligner according to claim 4 characterized by adjusting the refractive index of the aforementioned liquid like

[Claim 7] It is the aligner of six the claim 1 characterized by having further a photosensitive substrate electrode holder holding the aforementioned photosensitive substrate, and equipping this photosensitive substrate electrode holder with the side attachment wall for filling the optical path between the aforementioned projection optical system and the aforementioned photosensitive substrate with the aforementioned liquid, and supply / recovery unit for collecting from the aforementioned photosensitive substrate electrode holder while supplying the aforementioned liquid to the aforementioned photosensitive substrate electrode holder, or given in any 1 term.

[Claim 8] The aforementioned refractive-index adjustment means is the aligner of seven the claim 1 characterized by having the additive supply unit which supplies the additive for adjusting a refractive index to the aforementioned liquid, and an additive recovery unit for collecting the aforementioned additives from the aforementioned liquid, or given in any 1 term.

[Claim 9] The exposure method characterized by to include the process which adjusts the refractive index of the aforementioned liquid for the image-formation performance of the aforementioned projection optical system to an amendment sake in the exposure method of leading the light from the aforementioned projection optical system to the aforementioned photosensitive substrate through a predetermined liquid including the process which illuminates a reticle, and the process which imprints the pattern prepared on the aforementioned reticle to a photosensitive substrate using a projection optical system under predetermined lighting conditions.

[Claim 10] The process which illuminates a reticle under predetermined lighting conditions, and the process which imprints the device pattern prepared on the aforementioned reticle to a photosensitive substrate using a projection optical system are included. The device manufacture method characterized by changing the refractive index of the aforementioned liquid in the device manufacture method of leading the light from the aforementioned projection optical system to the aforementioned photosensitive substrate through a predetermined liquid when at least one side is changed among the aforementioned reticle and the aforementioned lighting conditions.

[Claim 11] the manufacture method of the aligner exposed through the liquid which it has the lighting optical system which is characterized by providing the following, and which illuminates the pattern prepared on the reticle, and the projection optical system which forms the image of this pattern on a photosensitive substrate, and a part is boiled in the optical path between the aforementioned projection optical system and the aforementioned photosensitive substrate at least, and is located The process which measures the image formation performance of the aforementioned projection optical system The process which defines the initial value of the refractive index of the aforementioned liquid based on the measured this image formation performance

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[Translation done.]

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